TESLA LC ⇄ European XFEL

R. Brinkmann, ITRP Meeting DESY, April 2004

XFEL Project - brief overview

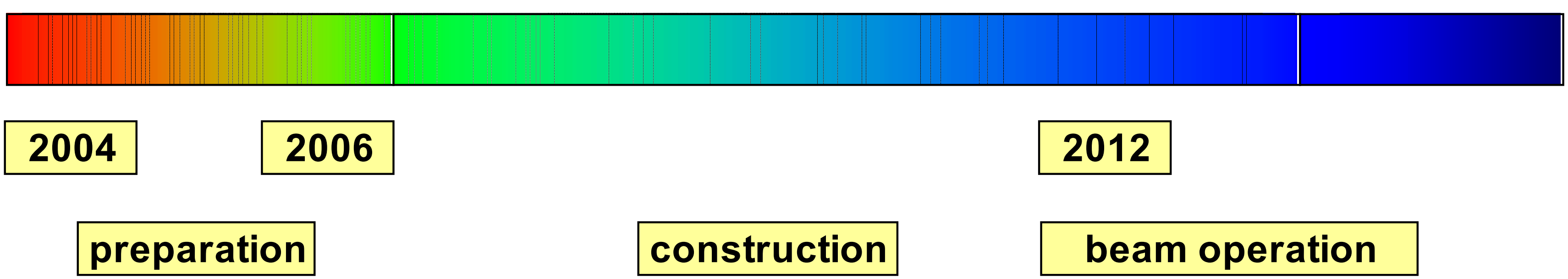
- 4th generation SR user facility with SASE-FEL concept in the 1 – 100 Angstroem ($\rightarrow$ 0.5Å) wavelength (1st harmonic) and 100fs ($\rightarrow$ < 1fs) pulse length regime

- In 1st stage 3 SASE & 2 spontaneous undulator beam lines, 10 experimental stations

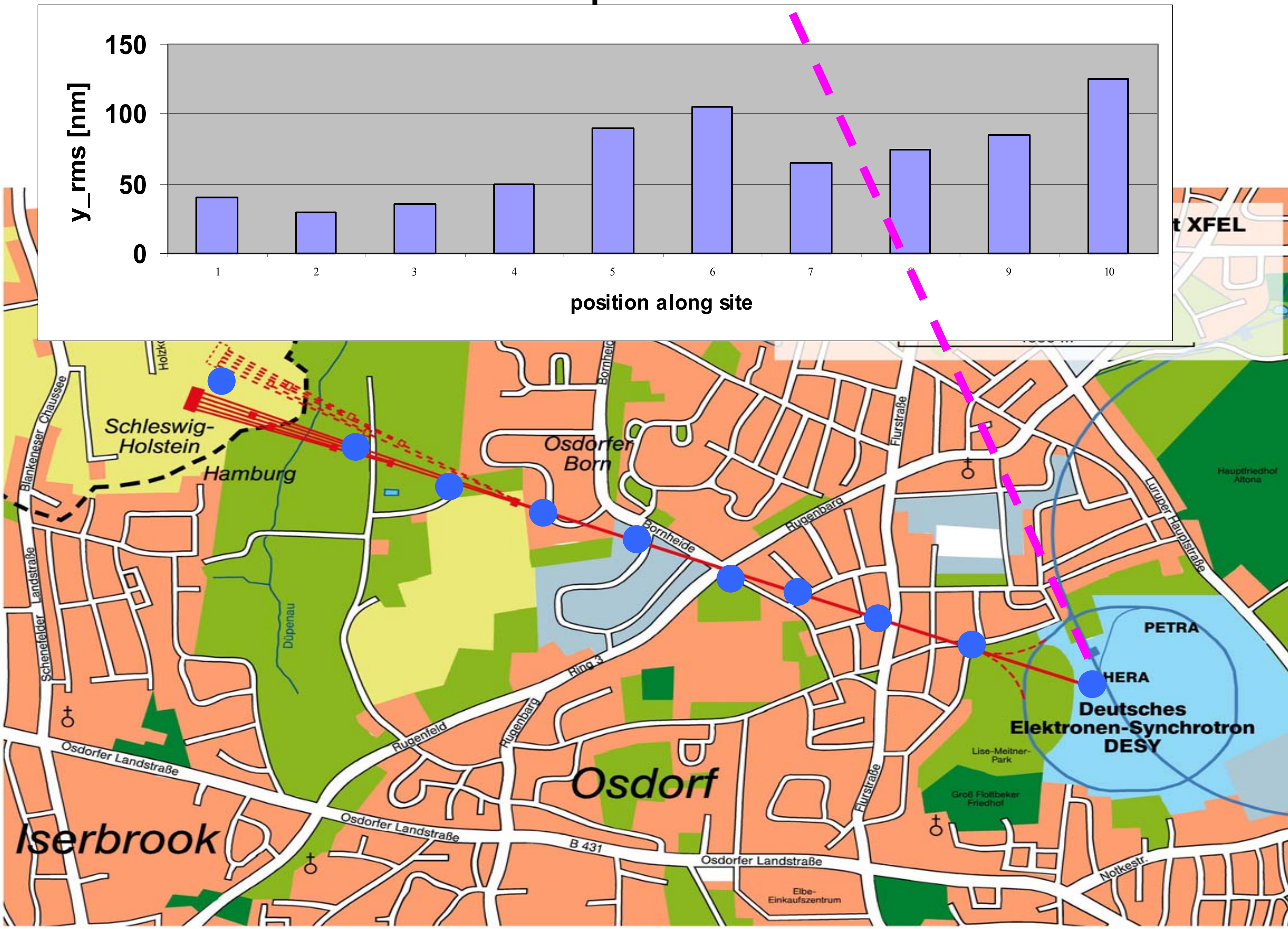
- Driver: 1.5km linac in TESLA technology, 20GeV beam energy @ 23MV/m gradient

Overview cont'd

- German government Feb. 2003: go-ahead for XFEL as European project, incl. funding 50% of total 684 M€ (year 2000) project cost, + contribution from Länder HH & Schleswig-Holstein, ~ 40% European Partners
- Project organisation at Europ. Level (scientific/technical & administrative/financial) ongoing, completed in 2005



New XFEL site: independent from LC site

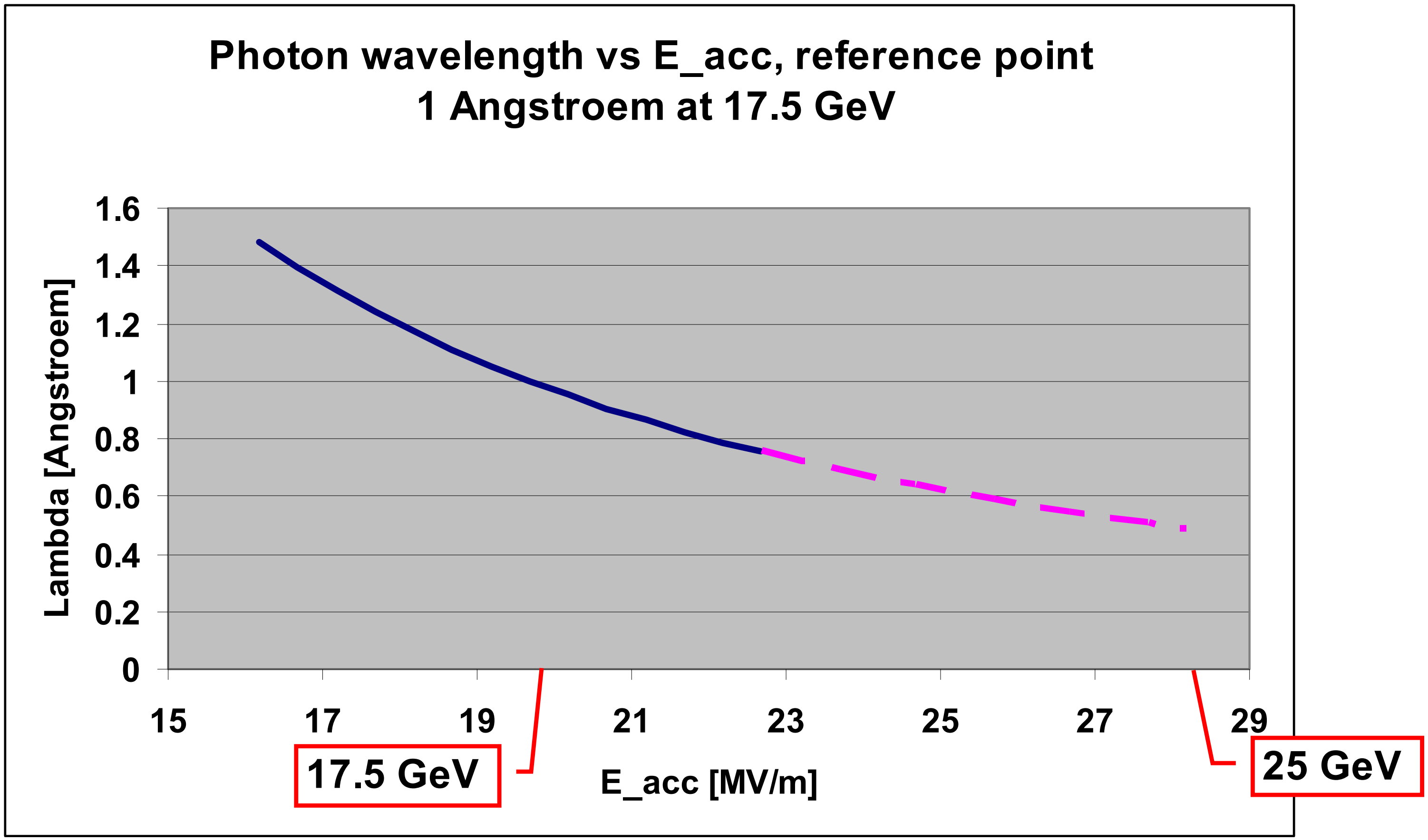


Accelerator reference parameters

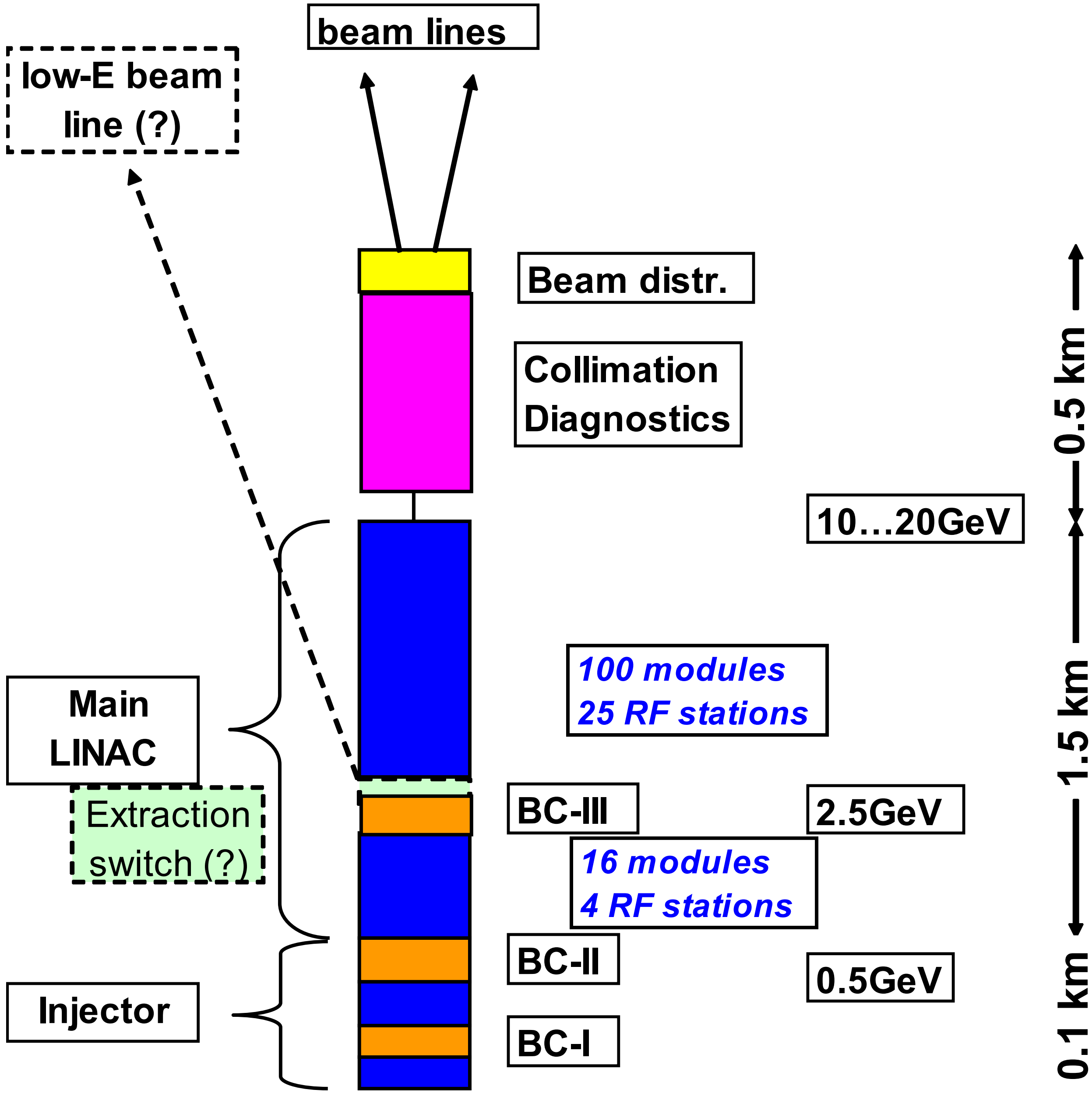
Main linac	
Energy gain	0.5 → 20 GeV
# installed modules	116
# active modules	104
acc gradient	22.9 MV/m
# installed klystrons	29
Bunch spacing	200 ns
beam current	5 mA
power→beam p. klystron	3.8 MW
incl. 10% + 15% overhead	4.8 MW
matched Q_{ext}	$4.6 \cdot 10^{6}$
RF pulse	1.37 ms
Beam pulse	0.65 ms
Rep. rate	10 Hz
Av. Beam power *	650 kW
Total AC power	≈ 9 MW

* Power limitation to ~300kW per beamline → solid beam dump possible

Photon wavelength vs. acc gradient



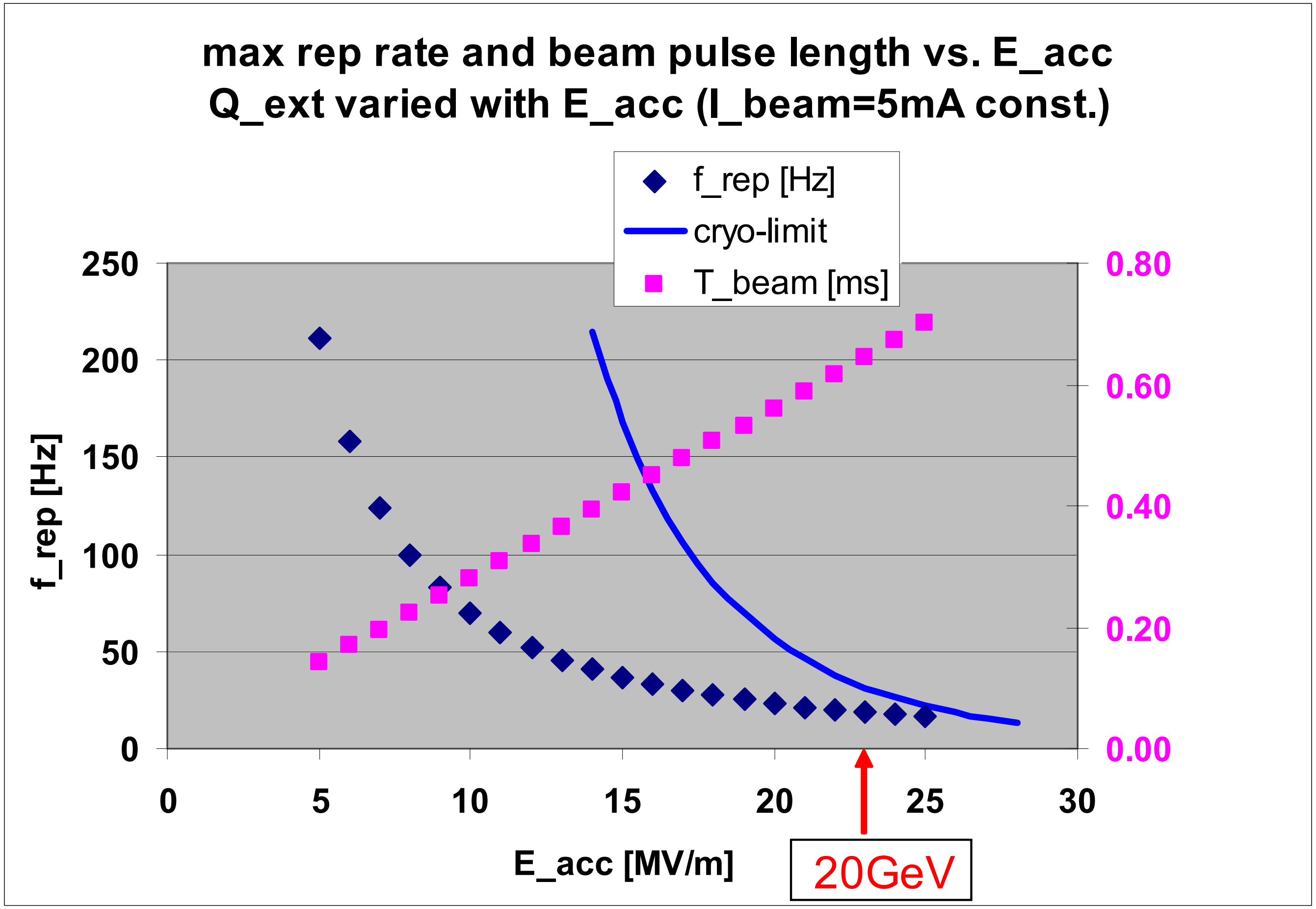
→ 25 GeV is reasonable upper limit for layout of beam line magnets



beam lines
low-E beam line (?)
Beam distr.
Collimation
Diagnostics
10…20GeV
0.5 km
100 modules
25 RF stations
1.5 km
Main LINAC
Extraction switch (?)
BC-III
2.5GeV
16 modules
4 RF stations
BC-II
0.5GeV
Injector
BC-I
0.1 km

Linac technology

- Will build 120 accelerator modules (~ 1000 cavities) and 32 RF stations in industry – requires ***everything*** also needed for the the LC, except:
  - **17m (12 cav's) instead of 12m (8 cav's) modules *(marginal gain in fill factor)***
  - **Shortened inter-cavity spacing & superstructure *(fill factor/cost advantage not well balanced with extra R&D effort)***
  - **RF stations de-rated in peak power – not in average power! *(higher rep rate/duty cycle desirable by users)***



Cryogenic plant equal to one of the six TESLA-500 LC plants →

Cryogenic limit for CW operation is E_{acc} = 7MV/m (6 GeV), **if $Q_0=2\cdot10^{10}$**

Layout with ***single*** linac tunnel

E.g.:

Electronics in tunnel/radiation environment (→ test in DESY-LINAC-II)

Handling of RF and cavity, power supply failures

Stray fields?

Supports and alignment

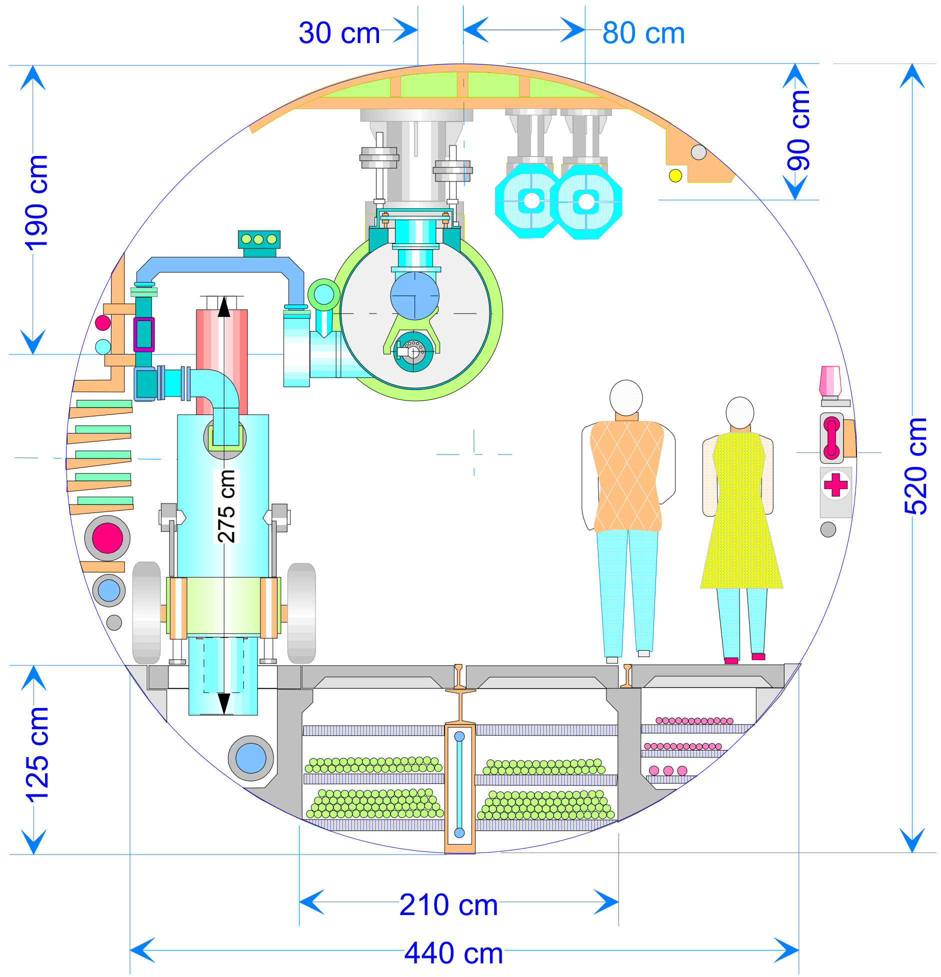


Figure 3. Main LINAC, Damping Ring & Klystron Station

Beam dynamics

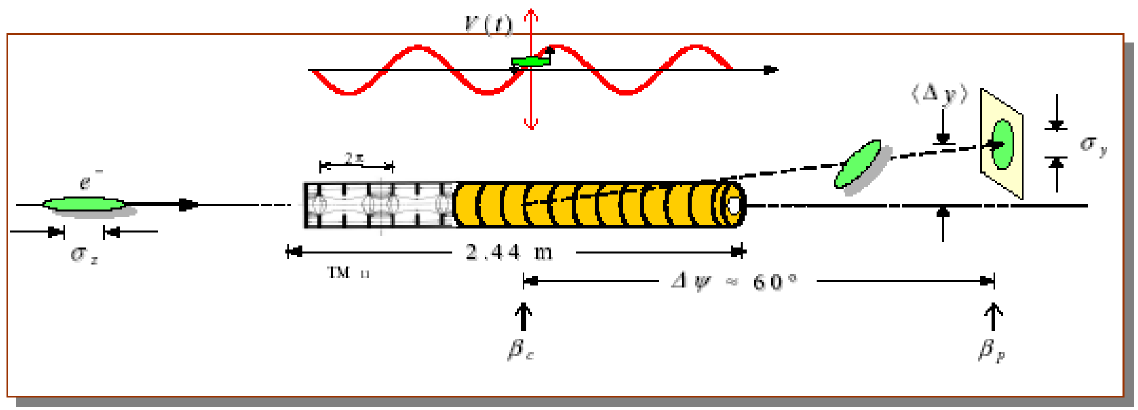
(assuming same alignment tolerances; comparison not exhaustive; rough scaling ±factor 2 for some of the XFEL parms)

Issue	parameter	TESLA LC	XFEL	comment
m.b. transverse wake	peak orbit ampl.	1σ	0.2σ - 0.4σ	intra-train feed-forward!
BC / Φ_{RF} error	ΔE, time, σ_z	O(0.1°)	O(0.01°)	
Synchronisation	Δt	<0.5ps	<0.05ps	
1µm Orbit stab. BDS / undulator	$\Delta\varepsilon/\varepsilon$ / $\Delta y'$	few %	$0.1\sigma'$	intra-train feedback!
Energy jitter	$\Delta E/E$	O(10^{-4})	(O10^{-4})	

Beam dynamics cont'd

- Inertial an non-inertial (CSR!) space charge effects very critical for XFEL → advanced instrumentation and beam diagnostics required (e.g., bunch slice analysis)

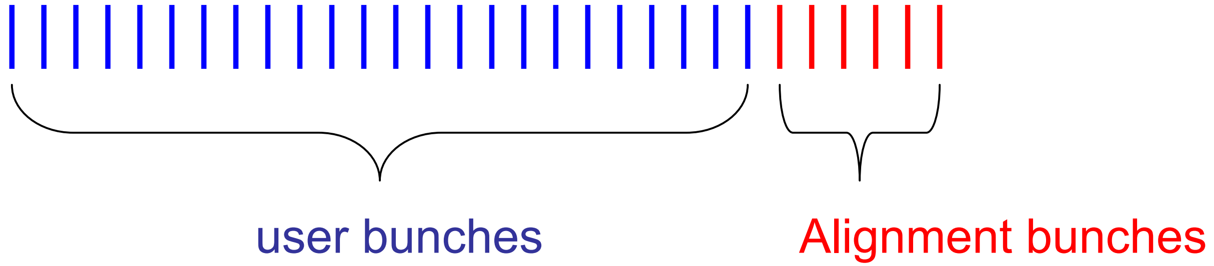
(example for coop. with SLAC)



- We have obtained and will obtain more invaluable experience from TTF & VUV-FEL!

Intra-train beam stabilisation

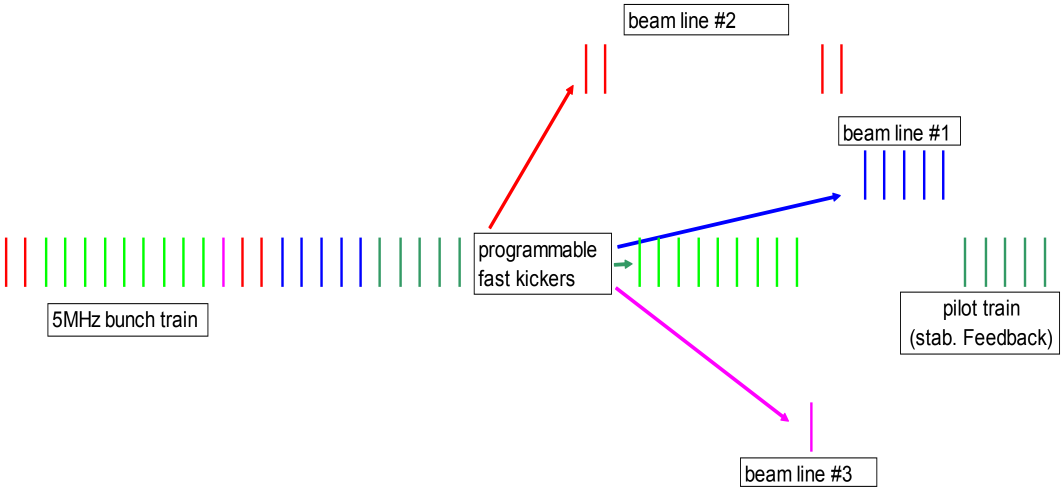
- From ground vibration: jitter ~ 0.1σ at end of linac
  - Can be enhanced during “single events” e.g. heavy traffic, and by quad support eigenmodes
  - Other effects: stray fields, HOMs, …
- → feedback system between linac and distribution to undulators

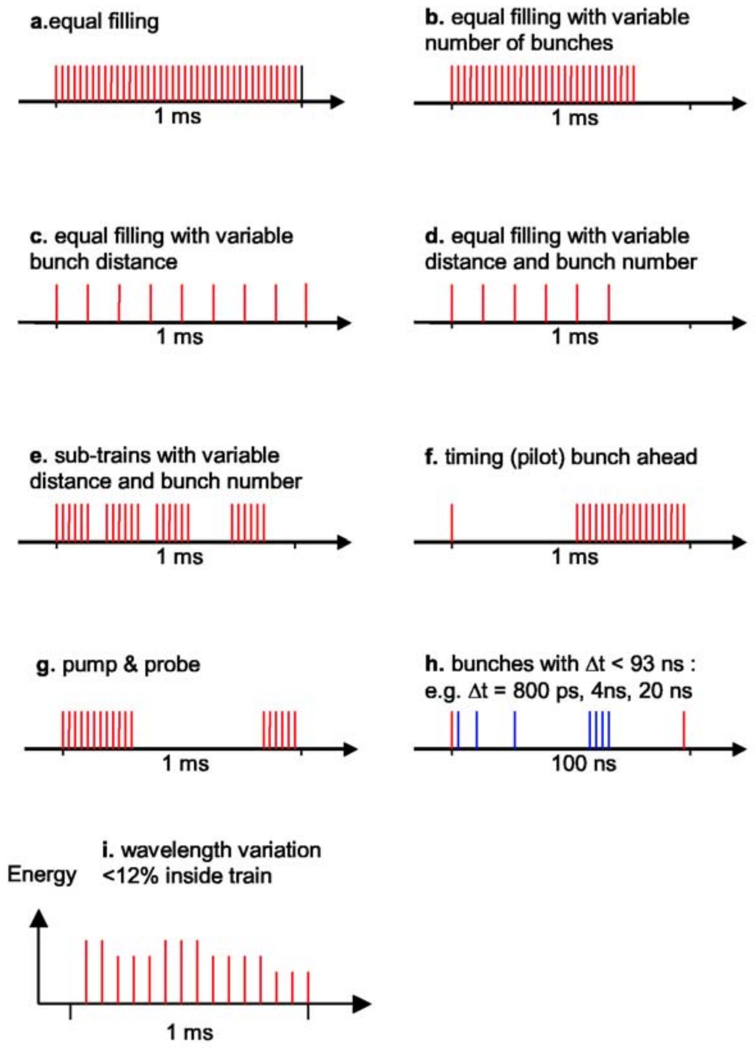


Also active stabilisation of energy and possibly other beam parameters

Different users – different time structures

- Generation of bunch train patterns:
  - At the source → varying transient effects in the entire accelerator (handled e.g. by the LLRF system)
  - At the beam delivery/distribution system → more challenging kicker devices → **very similar to damping rings kickers!**





Conclusions

- Major components of the XFEL facility are the same as (or very similar to) the ones needed for the s.c. Linear Collider
- The benefits of the XFEL project for a later LC project regarding accelerator design, industrialisation, fabrication and testing of components, operational aspects (controls, reliability, MPS, …) are obvious
- last, but certainly not least, the expertise and motivation of the scientists, engineers, technicians, … involved in the preparation and construction of the XFEL represent an invaluable “human capital” for a future s.c. LC project